THE SCIENCE OF PREVENTION

Statement of

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Chairman King and members, thank you for the opportunity to appear before the Committee on Homeland Security's Subcommittee on Prevention of Nuclear and Biological Attack to testify on the how the US Researach and Development (R&D) efforts are going in the area of countering nuclear terrorism. I am particularly interested in how well these efforts track the Recommendations of the 2002 National Academies Report, "Making the Nation Safer: The Role of Science and Technology in Countering Terrorism." I was the chair of the panel that wrote the chapter on Nuclear and Radiological Threats in that report. Ours was the first chapter after the introduction, and this reflected the consensus of the National Academies that the supreme terrorist threat to the United States is the detonation of improvised or stolen nuclear weapons in our cites.

My name is William Happer, and I am the Cyrus Fogg Brackett Professor of Physics at Princeton University. Though my present home is Academia, I have a long history of participation in national issues. I served as the Director of the Department of Energy's Office of Energy Research (now the Office of Science) from 1991-1993. I have been a member of the JASON group since 1976, where I first became acquainted with issues associated with nuclear weapons. I serve on the boards of a number of not-for-profit organizations, including the MITRE Corporation. I was a co-founder of a successful medical imaging startup company, Magnetic Imaging Technologies, Inc., which was based on technology developed by my academic research group over the years. Perhaps most pertinent to this testimony, I served as a member of the Science and Technology Advisory of the Department of Homeland Security's Directorate of Research and Development, so I had a good opportunity to observe DHS's research and development activities while the advisory committee functioned.

During the time I served on that committee the Domestic Nuclear Detection Office (DNDO) was established in DHS, and much of my testimony will be focused on how well I think DNDO is doing. I offer several observations for the committee's consideration. These represent my personal views, and not necessarily those of the organizations with which I am associated.

Observation 1: The DNDO is addressing the supreme terrorist threat to our country, the detonation of an improvised or stolen nuclear weapon in one of our cities. While preparing to write its report, The National Academies Panel on Nuclear and Radiological Threats that I chaired received many briefings on research and development projects related to this area. What we learned, much of it at the classified level, left no doubt that the consequences of a terrorist nuclear weapon detonated in a US city would be at least 100,000 prompt casualties, unprecedented property damage, and lingering consequences from radioactive contamination. Helping to prevent these nightmare scenarios is DNDO's most important job, so we should support them in every way we can.

Observation 2: A big part of stopping nuclear terrorism should be activities beyond our shores. Unlike many non-nuclear explosives, or agents for chemical and biological terrorism, neither highly enriched uranium (HEU) nor plutonium can be made without massive infrastructure that could not be supported by a terrorist organization. The special nuclear materials will have to be acquired from states that already possess that infrastructure. The first and most effective line of defense from nuclear terrorism is to prevent terrorist organizations from acquiring special nuclear materials in any way – for example, from state sponsors, by theft, armed robbery, or by purchase on the black market.

Nuclear weapons and special nuclear materials in the United States are very carefully controlled, so the most likely sources of nuclear weapons or the materials to improvise them will be in foreign countries. Stopping special nuclear materials at their foreign sources is beyond the mandate of DNDO, but as we support DNDO's activities, we should also be sure that those government agencies and programs, charged with keeping these materials out terrorist hands, are appropriately supported. For example, the work on Materials Protection and Accountability that the US has sponsored in countries of the former Soviet Union has made a very important contribution to our nuclear security. I hope that this committee will work other Congressional committees to optimize the entire defense strategy against nuclear terrorism, both the domestic and foreign components.

Observation 3: DNDO should put most of its focus on nuclear explosives, not radiological dispersal devices (dirty bombs). The dispersal of radioactive materials with conventional explosives has gotten a lot of press attention, and we certainly would like prevent the use of a “dirty bomb” like this. But study after study has concluded that dirty bombs are not a very good terrorist weapon. The radiation from the bomb is unlikely to kill anyone, although the dispersing explosive could be lethal. No doubt there would be great public alarm, well out of proportion to the actual damage of a dirty bomb, and it is appropriate to make plans to deal with this, in advance. For example, a more scientific approach to what constitutes radioactive contamination would be very helpful. Because of the higher elevation, the background radiation dose in Denver is several times higher than in New York City or Washington. With good reason, residents of Denver do not worry about this. But with present regulations and public pressure, we might be forced to declare parts of east-cost cities uninhabitable where the residue from a dirty bomb raised the background radiation levels to those of Denver. This would be silly. It would be much easier to make that point now than after an incident. I believe that DHS through its various agencies is already addressing this problem, and they should continue.

The large amounts of radioactive material needed to make a dirty bomb are much easier to detect than the relative feeble signals from HEU or plutonium. But a massive national network of detectors to make life hard for dirty bombers is not a good use of limited resources of funds and competent people. We should certainly consider such a network if it could be effective against real or improvised nuclear weapons in terrorist hands.

Observation 4: Detecting nuclear weapons is very hard. Recalling 1946 Senate testimony by Robert Oppenheimer, Kai Bird and Martin J. Sherwin (April 25, 2005 issue of The Nation) wrote:

> Sometime that year he was asked in a closed Senate hearing room "whether three or four men couldn't smuggle units of an [atomic] bomb into New York and blow up the whole city." Oppenheimer responded, "Of course it could be done, and people could destroy New York." When a startled senator then followed by asking, "What instrument would you use to detect an atomic bomb hidden somewhere in a city?" Oppenheimer quipped, A screwdriver [to open each and every crate or suitcase]."

What was true in 1946 remains true today. It is very difficult to detect special nuclear materials without very close inspection.

Both uranium, and especially plutonium, are radioactive. Their gamma radiation and neutrons can penetrate many packaging materials. Given close access to the uranium or plutonium, sufficient time, and good passive detectors of gamma rays or neutrons, it is possible to identify special nuclear materials. The energy spectrum of the gamma rays is especially useful. But HEU has a very feeble signal and is especially hard to detect. And while plutonium is much more radioactive than HEU, it can be effectively shielded. Lead is a very good shield for gamma rays. It is worth remembering that the sailors of our ballistic missile submarines bunk close to plutonium-containing warheads, but the locations and shielding are such that the sailors do not receive an unacceptable dose of radiation during their sea duty.

Instead of relying on the self-radioactivity of SNM, there have been many proposals to use active probes that irradiate suspicious packages with x-rays, gamma rays or neutrons. I believe that DNDO is sponsoring work on a number of these active devices, and it is entirely appropriate that they do so. We need to assess how well active probes could work in practice.

Given the resourcefulness that terrorist organizations have shown in the past, one would have to assume that they will make every effort to avoid instrumented ports of entry. For example, to avoid detection at unexpected instrumented sites, the SNM could be shielded, or it could be divided into smaller, harder-to-detect pieces to be assembled later in a location that is safe for the terrorists. At the website, http://www.lanl.gov/history/people/agnew.shtml you can see a picture of the core of the Nagasaki bomb, held by Harold Agnew, a former director of Los Alamos on Tinian Island. The point is that Harold had no difficulty holding the package, about the size of a shoe box, in his left hand. While somewhat larger amounts of HEU are needed for a bomb than Pu, the materials we need to intercept are not very large and they are relatively easy to conceal and to envelop in radiation shields.

Observation 5: Improvements, but no breakthroughs, can be expected from R&D work on passive detectors. I occasionally read about the need for a Manhattan Project to improve nuclear radiation detection. I am sure that worthwhile improvements in passive detectors are possible, but these are almost certain to be incremental and not breakthroughs. To add a little substance to this discussion, recall that the two most common types of gamma-ray detectors are scintillation detectors and solid-state detectors.

In scintillation detectors the gamma ray is absorbed in a transparent material and produces scintillation, a flash of light in the material. The light flash reveals that the gamma ray has been absorbed and the brightness of the flash can be used to estimate the energy of the gamma ray. Typical scintillating materials for gamma-ray detectors with fairly good capabilities to measure the energy of the gamma ray are crystals of sodium iodide or cesium iodide with trace impurities to increase the brightness of the light flash. A big advantage of most scintillation detectors is that they operate at room temperature and require no special cooling. The main disadvantage is the limited ability of scintillation detectors to measure the exact energy of the gamma ray.

In a second type of detector, the solid-state detector, the gamma ray releases electric charges in a semi conducting material. The pulse of current from these charges reveals the presence of the gamma ray. The amount of charge collected is an excellent measure of the gamma ray's energy, much more precise than for a scintillation detector. The high energy resolution makes it possible to unambiguously identify uranium, plutonium and even the isotopic composition of these materials if they are present in sufficient quantities and there is sufficient time for the measurement. A disadvantage of solid-state detectors is that the best ones, for example, intrinsic high-purity germanium, need to be cooled to liquid nitrogen temperatures.

Both types of detectors have been the subject of many years of research and development. But a focused R&D program on passive detectors could lead to improvements in performance and better suitability for DNDO systems. For example, one could probably develop uncooled semiconductor detectors, by using semiconductors with larger band gaps than germanium, but this would come at the unavoidable cost of somewhat poorer energy resolution.

We live in a radioactive world and a gamma ray detector will also detect cosmic rays coming through our atmosphere from outer space, and ionizing radiation from naturally occurring materials. Granite building stone normally includes lots of uranium and thorium, and even bananas or people, with their naturally occurring content of radioactive ^{40}K, are noticeably radioactive and will trigger counts in gamma detectors. A good passive detector for finding special nuclear material will also be a good detector of background radiation. If the expected number of counts from the background is much larger than that of the package containing HEU or plutonium, no amount of detector improvement will help.

Neutrons can also be detected passively, and once again, there has been a great deal of work done over the past half century to improve the performance of neutron detection. Again, I see the possibility of modest improvements in passive neutron detectors but not breakthroughs.

Observation 6: Bigger improvements can be expected from R&D on active detectors than for passive detectors. An active detector uses some external probe to look special nuclear materials. For example, the probe could be a beam of x rays, gamma rays or neutrons. There has been much less work, over the years, on active detectors of special nuclear materials than on passive detectors. So there is more room for improvement here, especially in reducing the cost and making the packages more readily deployable at ports of entry. Active detectors will tend to be much more costly and cumbersome than passive detectors, since the equipment to make the probing beams is often expensive and additional passive detectors are needed as part of the overall system.

Observation 7: It is important to subject both passive and active detectors of special nuclear materials to rigorous experimental testing. Testing detectors for special nuclear materials under realistic conditions will be essential for real progress. Such tests are quite difficult to do. I already mentioned the need to keep special nuclear materials out of terrorist hands. An obvious place for terrorists to acquire such materials is where tests are being done with them. So realistic testing must be done with completely reliable security measures. Before the formation of DNDO there were plans to build a test facility at the Nevada Test Site, where there is long experience in handling special nuclear materials and real nuclear weapons. This was going to be an expensive facility, but I thought it was a good idea, and I hope that these plans are still on track.

Observation 8: An appropriate amount of funding should be set aside for basic research on radiation detection. In my previous observations I have focused on very near-term responses to keeping nuclear weapons out of the US. I think that a focus on these near-term problems is appropriate, given the immediate threats we are facing. But I would urge DNDO to champion a certain amount of basic research that is only loosely related to near-term radiation detection. Most of the instruments that DNDO is using now originated in basic research in nuclear and particle physics. Supporting high quality basic research on radiation detection would be a very wise investment. For example, some of the most exciting mysteries facing contemporary physics and astronomy are the nature of neutrinos. Of all currently known radioactive decay products, neutrinos are hardest to detect. Modest support of basic research in neutrino detection would be perfectly sensible for DNDO or one of its partner agencies with the mission to defeat nuclear terrorism. Another great mysteries of physics and astronomy is the nature of the missing matter in the universe. Several academic groups are pushing the limits of radiation detectors in hopes of detecting this missing matter through hypothetical and extremely rare ionizing events. Dating geological samples with the feeble signals of parent and daughter radioactive isotopes is also an area where technology of interest to DNDO is being pushed to its limits.

DNDO should also support research on improving the detectors we already have. For example, some very promising new materials, both scintillators and solid state detectors, are currently impractical because no one knows how to grow the necessary high-quality crystals affordably and reliably. But this is not what I mean by basic research for the long term. It is hard to keep the most imaginative and motivated people working exclusively on improvements of existing detector technology, since the work does not lead to much peer recognition, publications in prestigious journals or to the excitement of discovery of previously undetectable types of matter.

If history is any guide, the sort of breakthroughs that could make DNDO much more effective in the long term are most likely to come from some unexpected finding in basic research. But since the timing of such breakthroughs is completely unpredictable, the best strategy is to focus on what can be done in the near future with existing or incrementally improved detectors, while keeping some modest fraction of the budget set aside for basic science that is loosely related to DNDO's goals.

Observation 9: An institutionalized red team should be part of DNDO. A planned nuclear attack on the US would probably be staffed with the most capable and technically competent terrorists who could be recruited by the parent organization. They will not be former proprietors of falafel stands, but they will include people trained in nuclear physics. Such experts would work to maximize the likelihood that a nuclear weapon can be successfully smuggled into the US. The US needs a red team of highly competent people that is assigned the same job – to defeat our national radiation detection system. Of course the findings of the red team should be classified, but the team should be encouraged to think expansively and with no constraints. Not only should they consider attempts to smuggle HEU through the instrumented San Isidro crossing near San Diego, but they should consider someone getting the small amounts of material needed across the long US land borders with Mexico or Canada, most of which is very loosely monitored. We have an extensive and beautiful coastline, and small boats regularly set out and return from uninstrumented harbors for deep sea fishing trips. DNDO needs avoid building a Maginot network of radiation sensors that invites the classic response to fixed defenses – to go around them.

Observation 10: DNDO needs a technically competent, independent advisory committee. DNDO should be required to seek advice periodically from independent advisory groups on both the scope and size of their efforts. When I served as the Director of Energy research in the Department of Energy from 1990 to 1993, I and my staff benefited from a number of very knowledgeable advisory groups. We did not always like their advice, but we often got very valuable and timely knowledge about science and technology developments we had missed because of the time pressures on those who work in the federal government. Such a group could provide the agency and the Congress with an independent assessment of the how well the DNDO programs are doing and of the resources needed to sustain an effective national effort.

Observation 11: DNDO needs appropriate and stable funding. Finally, the effectiveness of the DNDO effort will depend to a large extent on the adequacy, both in terms of magnitude and constancy, of the funding provided to undertake the work deemed to be important to homeland security. Regrettably, the threat of nuclear terrorism seems destined to remain with us for many years — technological capabilities to inflict massive harm on U.S. populations are becoming increasingly widespread and potentially accessible to terrorists worldwide. It will be necessary for the United States to mount an aggressive, long-term counter-terrorism R&D effort to stay at least one step ahead of terrorist capabilities.

This concludes my testimony to the committee. I would be happy to clarify my comments or answer committee members' questions. Again, thank you for the opportunity to testify.